BARBER COLMAN

IN 1211.6-3

MODEL 477P CAPACITROL

INSTRUCTION MANUAL

BARBER-COLMAN COMPANY
Industrial Instruments Div. • Rockford, Ill., U.S.A.

IN 1211.6-3

MODEL 477P CAPACITROL

INTRODUCTION

This instruction manual is designed to help you secure maximum benefits from your new Series 470 Capacitrol. It should be given to persons responsible for installation, operation and maintenance of this instrument.

Your Barber-Colman factory trained field engineer is always available for further help in the solution of your control problems. Offices are located in all principal cities.

BARBER-COLMAN COMPANY
Industrial Instruments Division

Litho in U.S.A.

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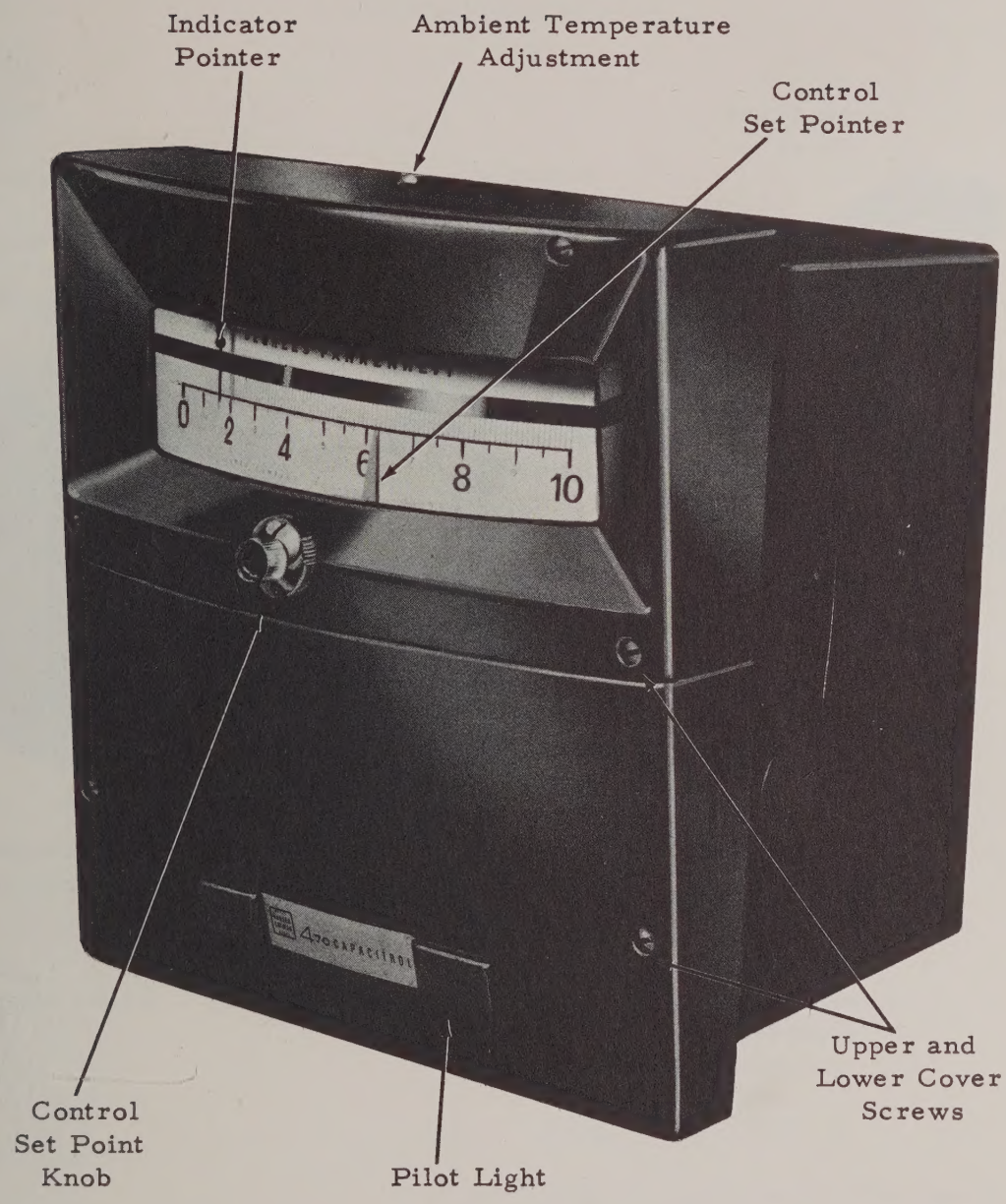
TABLE OF CONTENTS

	Page
Illustrations	i
Specifications	iii
Description	
General Description	1
Control Specifications	1
Description of Electronic Circuit	1
Proportional Control	2
Installation and Start-Up	
Unpacking the Instrument	5
Mounting Instructions	5
Power Wiring	5
Mounting Dimensions	6
External Wiring Diagrams	7
Meter Shunt Wire	12
Thermocouple Wiring	12
Thermocouple Break Protection	13
Thermocouple and Leadwire Resistance Compensation	16
Cold Junction Compensation	16
Operation	
Control Action	19
Control Adjustments	
Proportional Band Adjustment	19
Reset	20
Maintenance	
Routine Servicing	21
Measurement or Control Trouble	21
Calibration Check	22
Internal Wiring Diagrams	24
Replacement Parts List	26
Suggested Repair Parts	27
Definition of Terms	28



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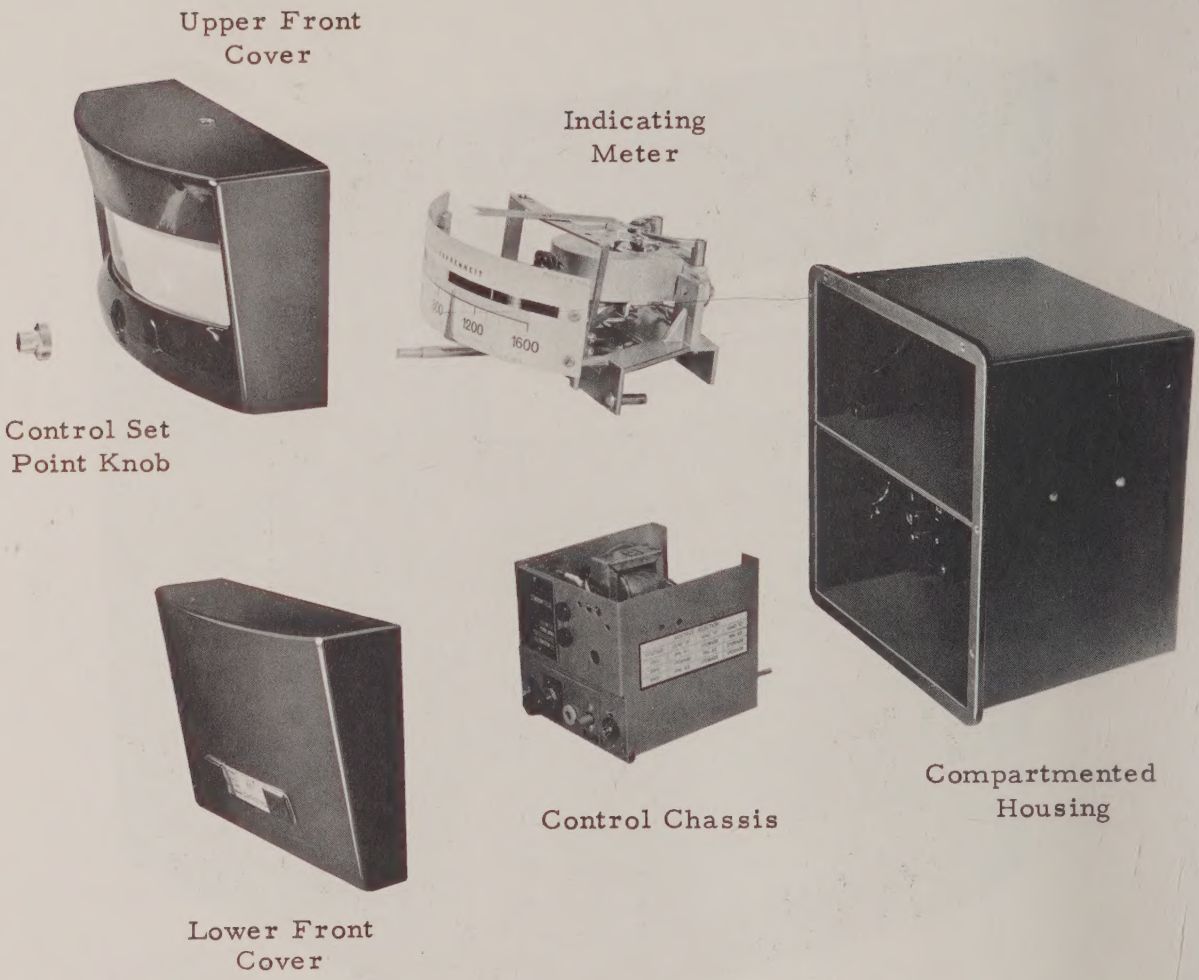


MODEL 477P

MAJOR COMPONENTS

F-12665

SPECIFICATIONS

Meter

Scale Length	6 inches
Minimum Span	9 mv or 0-300°F - Type J
Calibrated Accuracy	± 1/2% of full scale
Sensitivity	50 microamps for full scale deflection (nominal)
Internal Resistance	20 ohms per millivolt (nominal)
External Resistance	a) As standard, calibrated for 15 ohms and supplied with replaceable compensator to make up difference between calibrated resistance and actual value of external resistance. May be calibrated for other values of external resistance if required. b) Units with bridge type TCB are adjustable for external resistances up to 20 ohms
Compensation	a) Automatic cold junction temperature compensation -- mechanical standard; electrical optional. Range 40 to 130°F b) Copper coefficient compensation. Range 40 to 130°F
Thermocouple Break Protection	Standard type TCB furnished unless otherwise specified. Bridge type TCB available

Chassis

Control Output	Direct current
Control Output Span	2 to 12 milliamperes into 1500 ohm load
Proportional Band	Adjustable from 0.5% to 5% of full scale
Control Adjustment	External control set point knob adjustable over 100% of scale. Reset control internally adjustable
Power Requirements	9 volt amperes
Power Supply	Interchangeable: 120, 208, 240 volts a-c, 50 - 60 cycle

Dimensions and Weights

Overall Dimensions	9 15/16" high x 9 5/8" deep x 9" wide
Cutout for Flush Mounting	8 3/16" wide x 9 3/16" deep NOTE: Meter housing will extend approximately 6" into panel when flush mounted
Net Weight	Approximately 16 pounds
Shipping Weight	Approximately 23 pounds

MATERIAL WARRANTY

All equipment except tubes, photocells, and thermocouples, which within one year from date of shipment is found to have been originally defective, will be repaired (replaced if necessary) free of charge, if returned immediately, prepaid, to the factory at Rockford, Illinois. The seller shall not be liable to the purchaser, or to any other person, firm or corporation for any direct, indirect or consequential damages or injury of any kind or character; that by acceptance of such equipment the purchaser shall accept and assume all liability for any and all damages or injuries that may result from the use or misuse of such equipment by the purchaser, or by any other person, firm or corporation; and that there shall be no other warranty whatever, expressed or implied, with respect to such equipment.

DESCRIPTION

General Description

The Model 477P Capacitrol is a millivoltmeter-type indicating controller with a d-c current output for proportional control of an intermediate or final control device. It is used as the primary control instrument for driving magnetic amplifier/reactor systems or silicon controlled rectifier power controllers for the proportional control of load power.

Control Specifications

The Model 477P Controller has a proportional direct current output of 2 to 12 milliamperes and is designed to be used with a 1500 ohm load. Two adjustments, "Reset" and "Proportional Band", are adjustable from the front of the instrument. Their operation is described under "Control Adjustments". The proportional band is adjustable from 0.5% to 5% of full scale. Proportional control action occurs when the meter indicator is within the proportional band range of the instrument, with its position on the scale determined by the red control set pointer. After the controlled load has become thermally stable, any offset between the meter indicator and the red control set pointer can be corrected with the reset adjustment as described under "Control Adjustments".

The control point can be easily adjusted through the full length of the instrument scale by means of a knob located just below the scale. The red signal light indicates when power is applied to the chassis. The output is from terminals 5 and 6, with terminal 5 of negative polarity and terminal 6 positive.

Description of Electronic Circuit

The Model 477P incorporates a transistorized oscillator and d-c amplifier, with the d-c output of the amplifier controlling an external power controller which, in turn, controls the load power. At a position on the scale below control point, the collector current of the oscillator transistor is of sufficient magnitude so the output of the d-c amplifier is greater than 12 milliamperes. As the indicator approaches control set point, a small vane or flag suspended from the indicating pointer passes between two flat coils mounted on the control set point arm. As the flag moves upscale between the coils,

the collector current of the oscillator transistor is reduced. With the flag fully between the coils, the collector current is decreased to a minimum so that the output of the d-c amplifier is less than 2 milliamperes. Proportional control action occurs when the flag traverses a fixed distance between the coils, as discussed under "Proportional Control". In the 477P the input to the d-c amplifier is proportional to the oscillator collector current, controlling the amplifier output. The proportional band is made larger or smaller by adjusting the level of feedback from the d-c amplifier to the oscillator, which regulates the oscillator collector current change with respect to flag movement. When there is no feedback the proportional band is at minimum, or 0.5% of full scale, and at maximum feedback the proportional band is increased to 5.0% of full scale or greater.

Proportional Control

Proportional control action provides a continuous linear relation between the value of the measured variable and the position of the final control element. Overshoot and undershoot is eliminated, and close tolerance control is maintained. As stated above, proportional control of the d-c output current occurs when the flag is between the coils, and its position in the coils automatically determines the output of the instrument in d-c milliamperes to an external power controller. The external power controller (or magnetic amplifier) is generally set up so that a 12 milliampere input from the 477P will result in maximum power applied to the load, and a 2 milliampere input will produce a minimum (or zero) power to the load. A means of controlling load power is therefore obtained. After the meter indicator has reached the proportional band (with the flag between the coils) and moves upscale toward the control set point, the instrument's output in d-c milliampere decreases. At control set point the output would be approximately 7 milliamperes.

Figure 1 is an example showing the instrument's proportional band (PB) curves for a 5% setting and a 0.5% setting. The 0.5% PB setting is obtained by turning the PB adjustment fully clockwise. Also, in Figure 1 are the 620 Series and Model 610A power transfer curves. The power transfer curves also assume that the input control winding resistance of the 610A and 620 Series is 1500 ohms. The curves give a relative indication of power output. For example, if a voltmeter was attached to the test jacks and the meter read 12 volts (8 ma with 1500 ohm load), the 620 Series power output would be 60% of maximum output power. If a Model 610A was used the output of the 610A would be about 42.5 volts d-c, which would be the input to a reactor used in conjunction with the 610A magnetic amplifier.

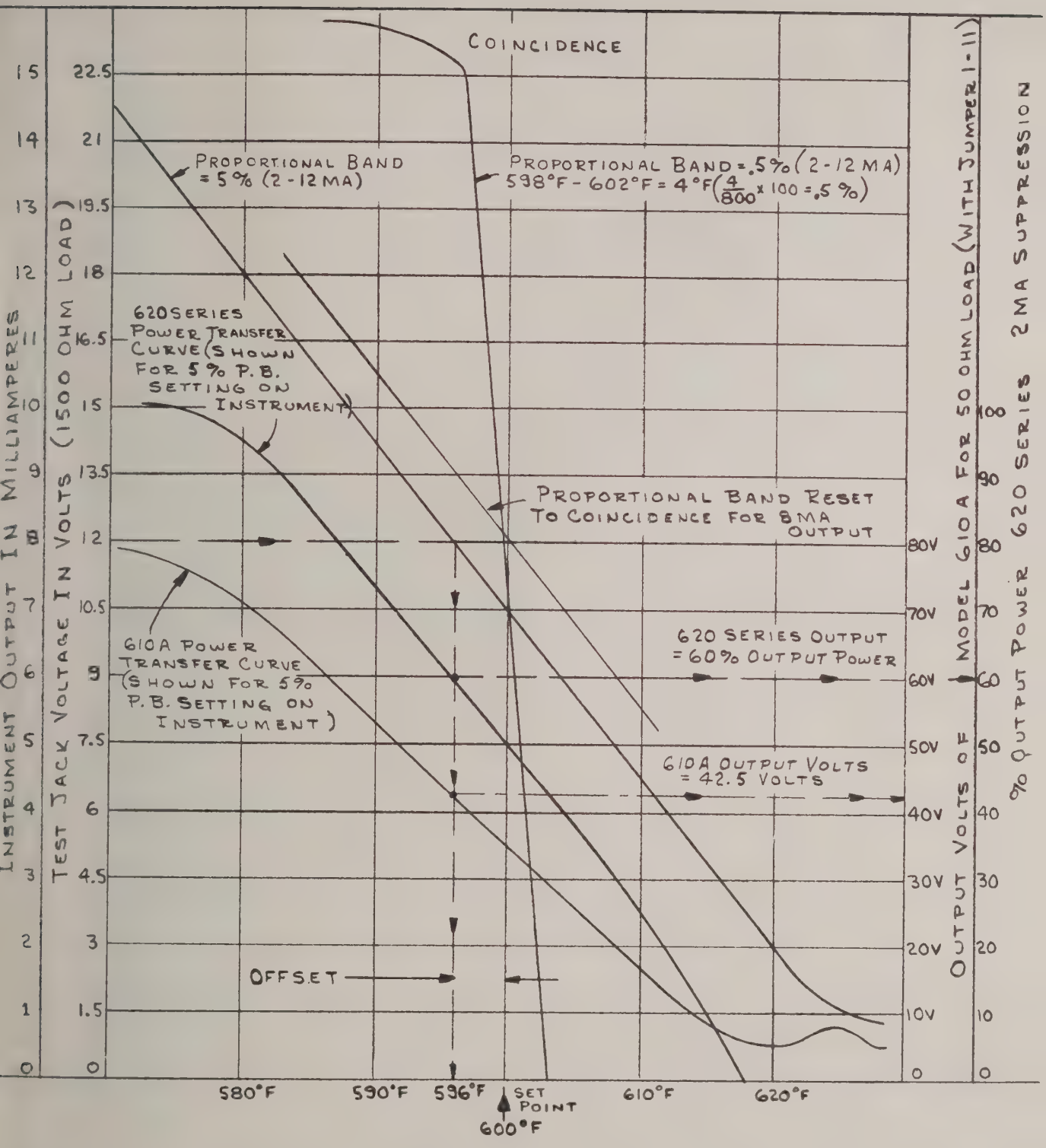

COINCIDENCE
PROPORTIONAL BAND = 5% (2-12 MA)
PROPORTIONAL BAND = 5% (2-12 MA)
598°F - 602°F = 4°F ($\frac{4}{800}$ x 100 = 5%)
620 SERIES POWER TRANSFER CURVE (SHOWN FOR 5% P.B. SETTING ON INSTRUMENT)
PROPORTIONAL BAND RESET TO COINCIDENCE FOR 8MA OUTPUT
610A POWER TRANSFER CURVE (SHOWN FOR 5% P.B. SETTING ON INSTRUMENT)
620 SERIES OUTPUT = 60% OUTPUT POWER
610A OUTPUT VOLTS = 42.5 VOLTS
OFFSET
580°F
590°F
596°F
SET POINT
600°F
610°F
620°F
INSTRUMENT OUTPUT IN MILLIAMPERES
TEST JACK VOLTAGE IN VOLTS (1500 OHM LOAD)
OUTPUT VOLTS OF MODEL 610A FOR 50 OHM LOAD (WITH JUMPER 1-11)
% OUTPUT POWER 620 SERIES 2MA SUPPRESSION

Figure 1

Example of Proportional Control Action
as the Meter Indicator Moves Upscale
Through the Proportional Band of a 0-800°F Meter

As shown in the example, the meter would indicate about 596°F which would mean an offset of 4°F from control set point. This offset is corrected using the reset adjustment as described under "Control Adjustments". The example shows the proper reset adjustments for the particular control point selected. In this example, the power transfer curves would also be shifted over the same amount as the proportional band curve.

In using the 477P in control systems, the proportional control of load power is obtained by using the direct current output of the 477P to control a magnetic amplifier (Model 610A) reactor combination or a Series 620 "SCR" power controller. The external wiring diagrams, pages 7 through 11, show typical connections. If reactors are used to control load power, a shunting resistor should be connected directly across the reactor control winding terminals, as shown in the wiring diagrams, to protect the reactor control winding in case the control circuit is opened under load, inducing a high voltage in the control winding.

As can be seen in Figure 1, there is always a small output when using a 610A or magnetic amplifier to drive a reactor. This results in a small amount of power always being applied to the load, even when the instrument's output is less than 2 milliamperes. Two power amplifiers are available to control reactors: the Model 610A - a magnetic amplifier, and the Model 630A - an SCR type controller with a d-c output. The specifications are as follows:

Model 610A	Excitation 120 v, 60 cycle; output - 5-75 v d-c, maximum power output to reactor control windings - 188 va. Used with reactors up to 30 kva rating.
Model 630A	Excitation 120 v, 60 cycle; output - 0-80 v d-c, maximum power output to reactor control windings - 750 va. Used with reactors up to 130 kva rating.

INSTALLATION AND START-UP

Unpacking the Instrument

This precision instrument and its associated equipment have been carefully manufactured and packed at the factory. Remove the instrument and accessories from the packing box and check items against the packing slip. If the equipment is found to be damaged in transit, report damages to the carrier immediately. Repack in original packing box until ready for installation.

CAUTION:

Handle with care.
Safeguard instrument from shock before and after installation.
Avoid oil accumulation and exposure to moisture.
Keep instrument temperature under 130°F and over 40°F.

Mounting Instructions

Locate instrument to avoid excessive vibration, shock and temperatures outside the range of 40°F to 130°F. Avoid furnace walls, radiation of heat, machine frames and outside walls. Provide suitable shelter against moisture and temperature extremes if installed outdoors. Refer to appropriate drawing for mounting details.

Power Wiring

The instrument is wired for 120 volts a-c. If available power supply is other than this, the proper voltage can be selected as follows:

The lower front cover should be removed by loosening the two screws. The chassis assembly can then be removed by firmly pulling forward. A voltage selection board is located on the top left side of the chassis. The voltage can easily be changed by plugging the wires onto the proper pins as shown on the right side of the chassis enclosure and as illustrated in Figure 2.

The two marked pins #1 and #2 are used for the voltage range desired while the other pins are used for storing the unused wires. The wires are marked A, B and C. The connections are as shown below:

VOLTAGE SELECTION

Voltage	Lead "A"	Lead "B"	Lead "C"
120 v	Pin #1	Storage	Pin #2
208 v	Storage	Pin #2	Storage
240 v	Pin #2	Storage	Storage

Figure 2

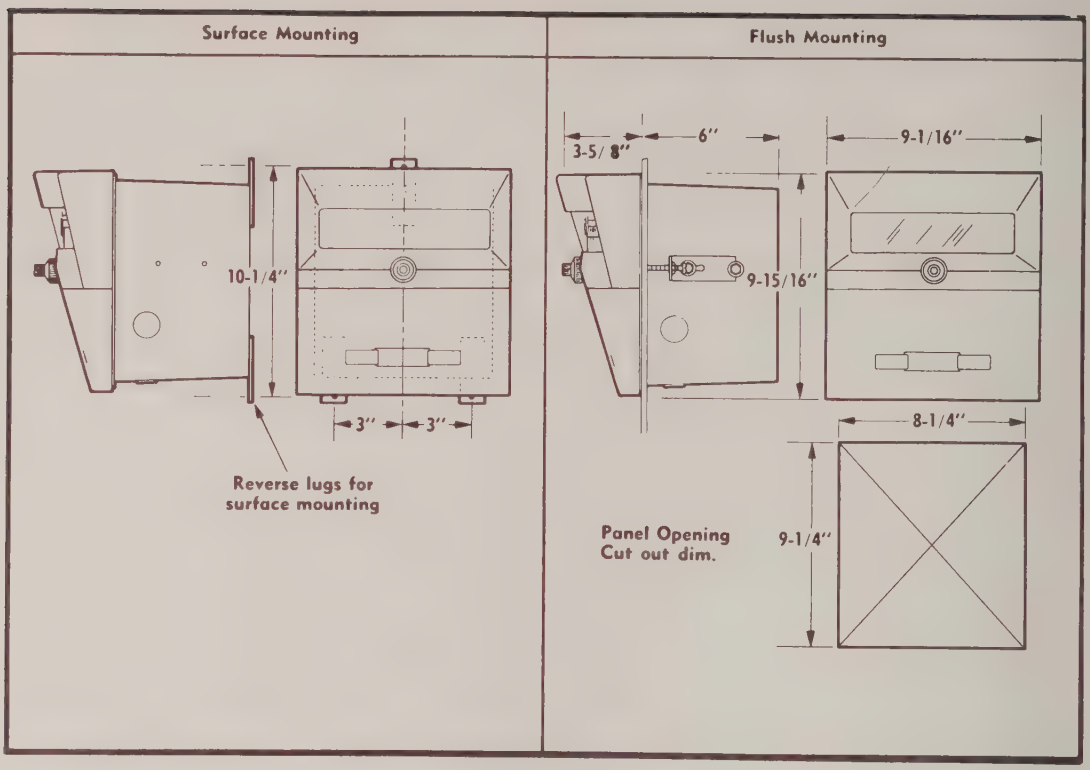


Figure 3
Mounting Dimensions
(Rigid Mounting)

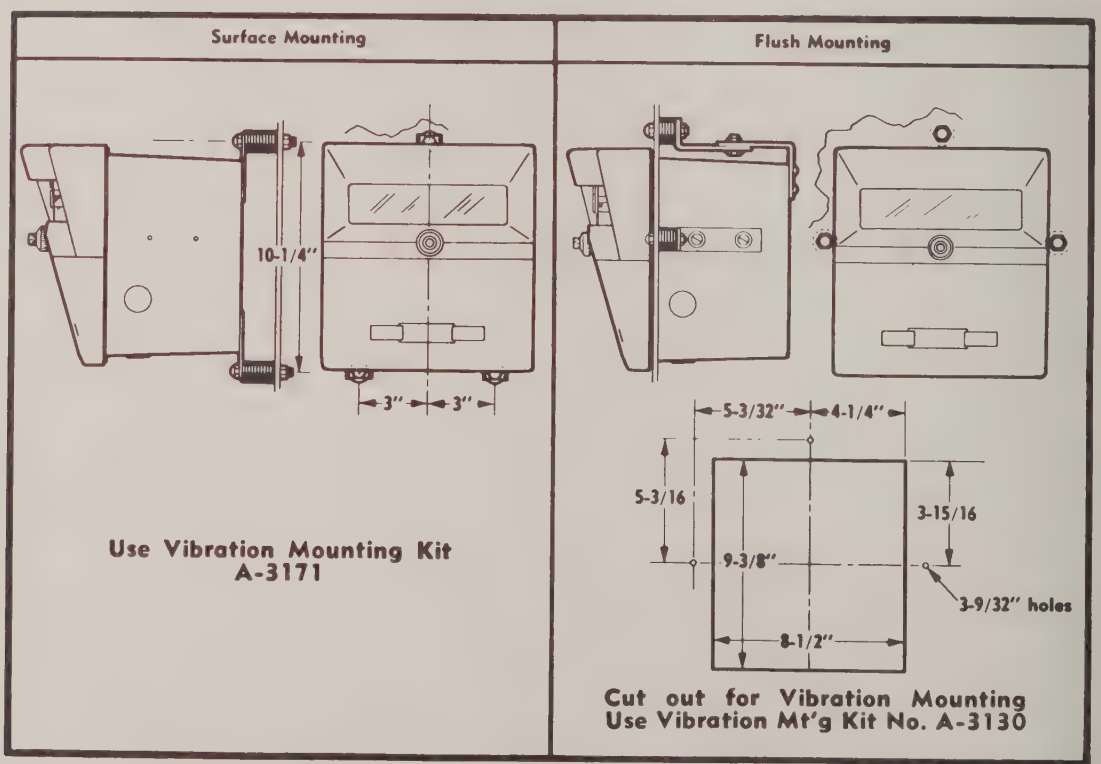


Figure 4
Mounting Dimensions
(Vibration Mounting)

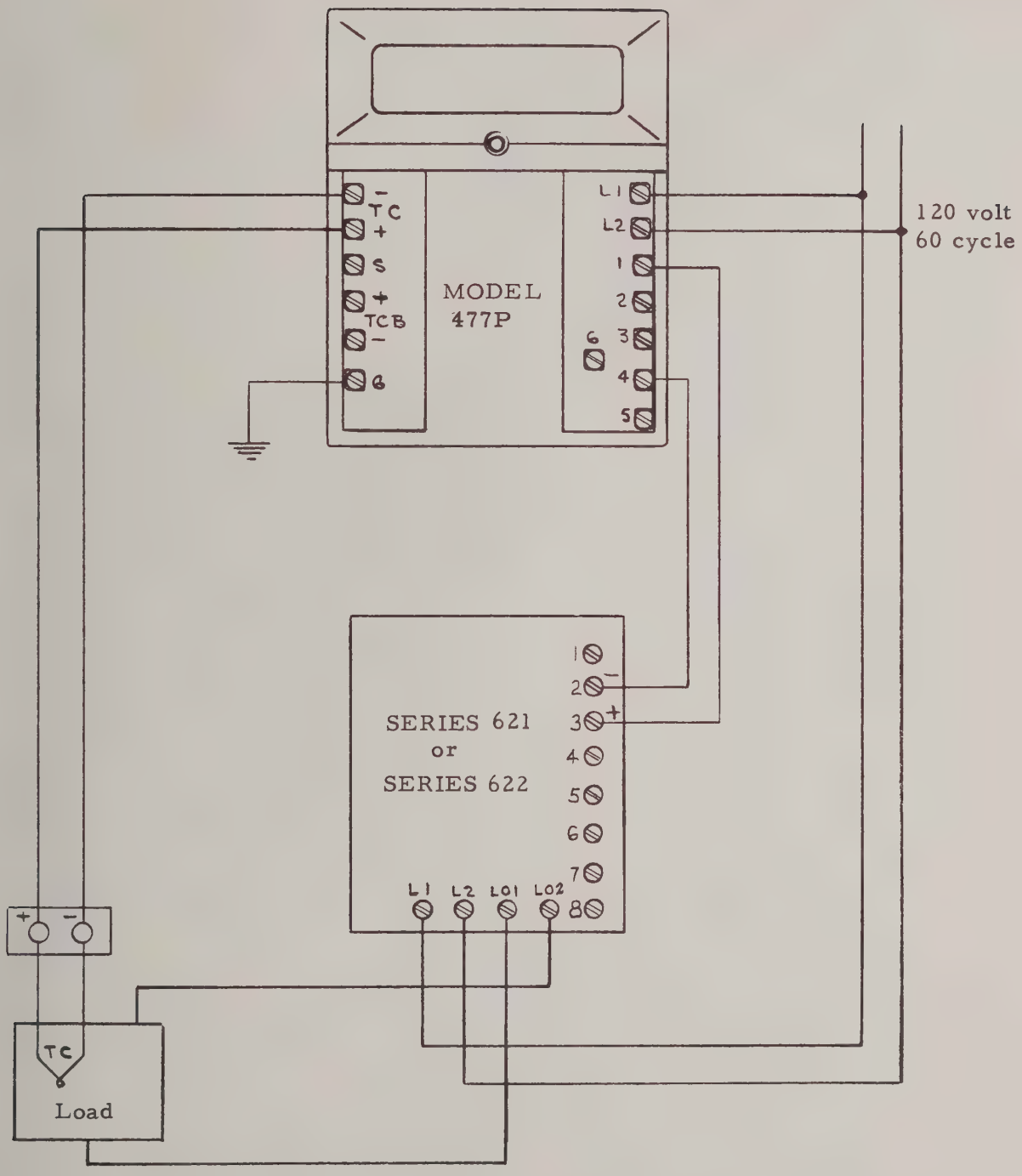
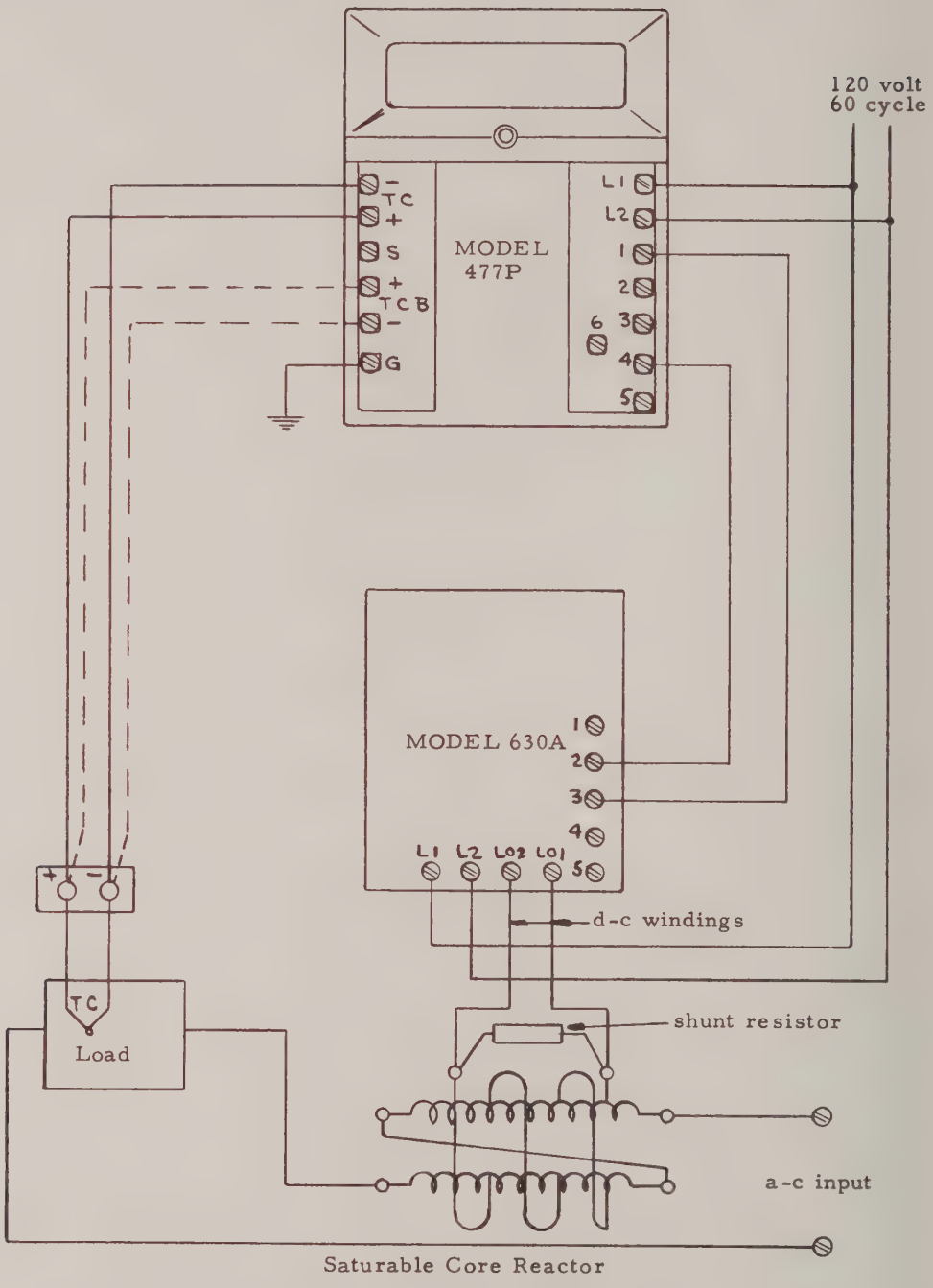


Figure 5

External Wiring Diagram of Model 477P Driving a Series 621 or 622 Power Controller



1. Reactor coils may be parallel connected for lower line voltage. Refer to manufacturer's specifications.
2. Identification of control winding terminals differ with various manufacturers.

Figure 6

External Wiring Diagram of Model 477P Driving a Saturable Core Reactor Through a Model 630A SCR Pilot Amplifier

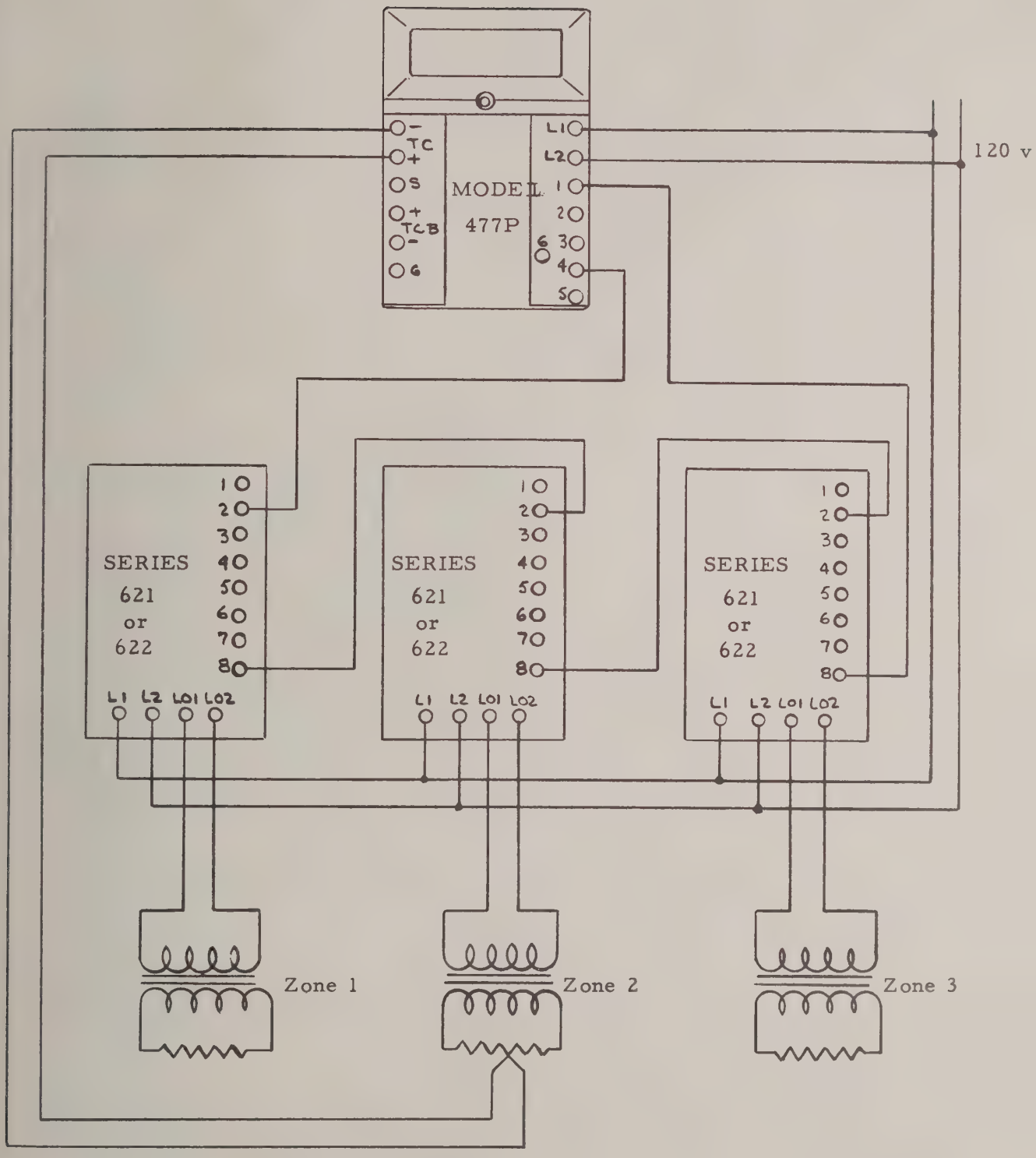


Figure 7

External Wiring Diagram of Model 477P Controlling Three Zones from a Central Zone using Series 621 or 622 Power Controllers

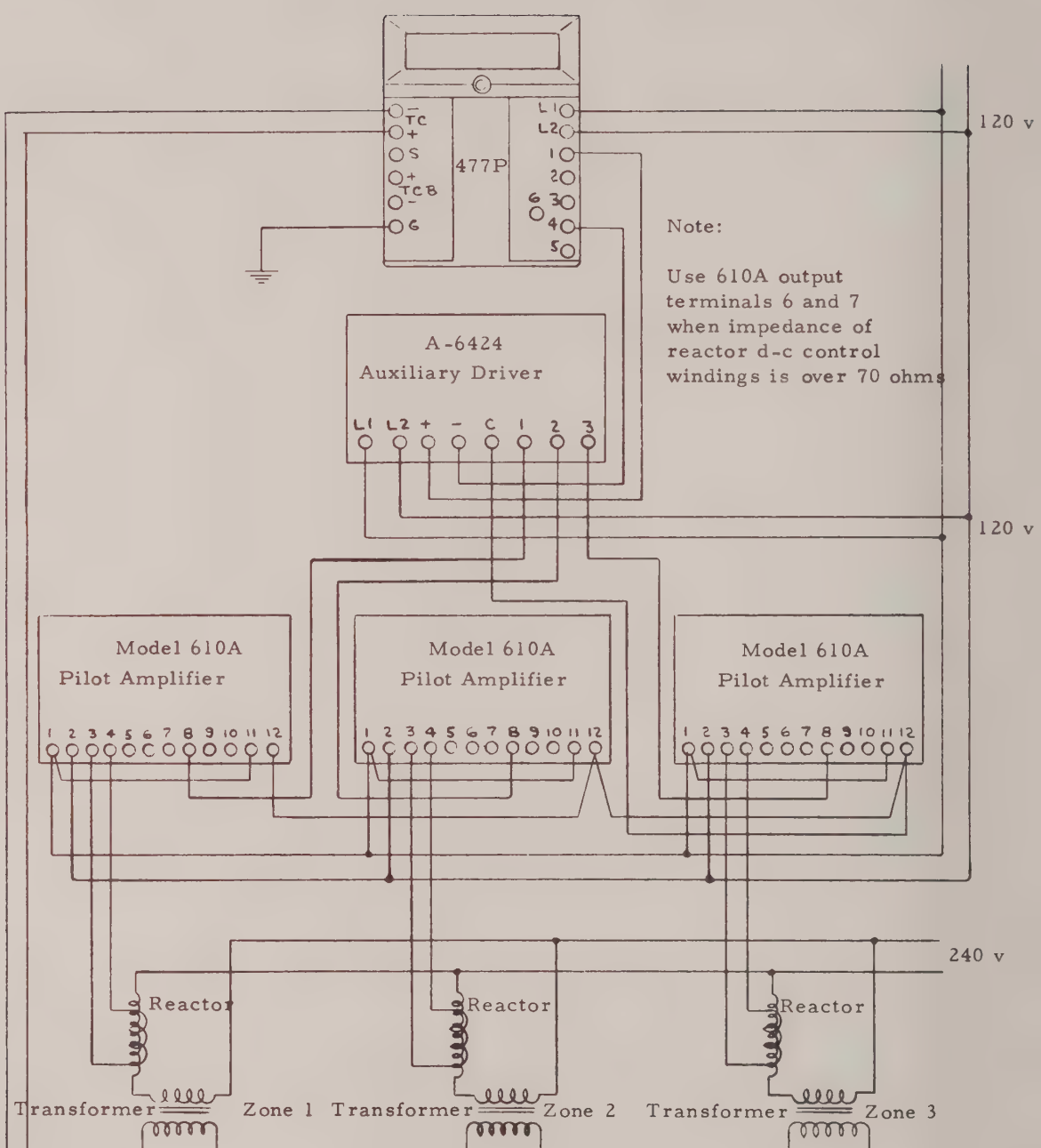
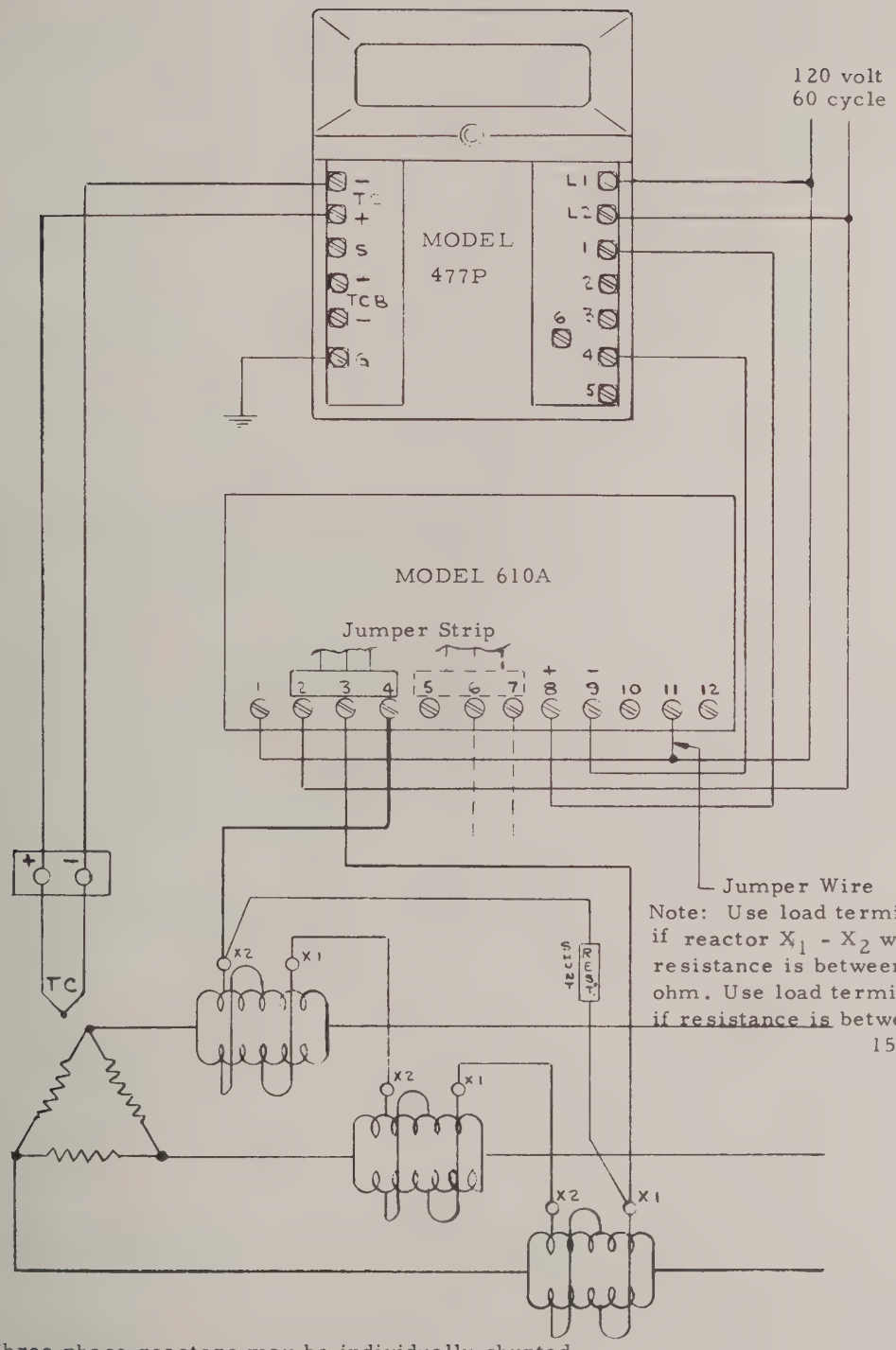


Figure 9

External Wiring Diagram of Model 477P Controlling Three Zones from a Central Zone using Saturable Reactors and Model 610A Pilot Amplifiers (note that an auxiliary driver is used for impedance matching)



Note: Three phase reactors may be individually shunted.
Reactor d-c coils may be parallel connected in special cases.
Refer to manufacturer's specification sheets accompanying reactor.

Figure 9

External Wiring Diagram of Model 477P Driving a Three-Phase Saturable Reactor Through a Model 610A Pilot Amplfier

After the proper voltage has been selected and the chassis replaced the instrument is then ready for wiring. The instrument will operate on both 50 and 60 cycle a-c systems. The desired a-c supply voltage is connected to terminals L1 and L2 inside the lower compartment. If the instrument is equipped for back wiring, remove the back panel to expose the terminal strips. All wiring should be in accordance with the applicable electrical codes. Where maximum protection of the instrument is desired a 1/8 ampere fuse may be added in the power line to the instrument.

Solid wire is recommended for instrument wiring. If stranded wire is used, tin the ends to provide secure connections.

The instrument should be grounded. This is accomplished by attaching the ground terminal (G) directly to a good ground, such as a cold water pipe.

CAUTION: Do not connect the ground terminal to the neutral a-c line.

Meter Shunt Wire

After the instrument is installed, disconnect the jumper wire across terminals marked "Shunt", "TC-" and "TC+". This wire is used to shunt or dampen the meter movement for protection during shipping, handling and installing the instrument, but should be removed for normal operation. Replace the shunt wire when handling or reshipping the instrument and position the red control set pointer fully upscale.

If the meter assembly is removed from the case, an automatic shunt device protects the meter assembly from damage. Other shunt wiring is not required.

Thermocouple Wiring

Do not run thermocouple leadwire with other power or control wiring. However, several thermocouple leadwires may be run in the same conduit if desired.

Use only extension leadwire correct for the type of thermocouple (TC) as specified on the scale. Except for certain radiation detectors, ordinary copper wire cannot be used. The types of sensing elements most commonly specified are:

Iron-Constantan	Type J
Chromel-Alumel	Type K
Platinum-Platinum 10% Rhodium	Type S
Platinum-Platinum 13% Rhodium	Type R
Heat-Eye Radiation Pyrometer	- - -

See Barber-Colman Thermocouple Catalog for a full selection of thermocouple assemblies and extension leadwire.

Proper polarity (+) and (-) of the leadwire must be observed to obtain correct readings. The negative wire is usually coded red. Correct polarity of the leadwire can be checked by forming a temporary junction at the far end, heating this junction with a match, and noting the deflection of the meter indicator. An upscale deflection is proof of correct polarity of the leadwire.

The thermocouple should then be connected to the leadwire and the indicating pointer should again deflect upscale when the thermocouple hot junction is heated. If the indicator moves downscale, reverse only the thermocouple connections at the terminal block since the leadwire has already been correctly connected to the instrument.

Secure the leadwires firmly under the terminal screws. If desired, spade lugs may be used.

Thermocouple Break Protection (TCB)

Each instrument is equipped with thermocouple break protection (TCB). If a break in the thermocouple circuit occurs, the meter indicator will be driven upscale past the control set point, causing the power to the controlled load or process to be turned off and guarding against overheating when an open thermocouple circuit occurs.

Two systems of thermocouple break protection are used. Standard models of the instrument are provided with a small d-c voltage wired into the thermocouple circuit to drive the movement upscale in the event of an open circuit. If so specified, bridge type TCB is furnished. With the thermocouple forming one leg of the bridge circuit, a break in the thermocouple or leadwire produces an unbalance causing the indicator to be driven upscale to shut off control power.

Note: Check to see that jumper wire on underside of chassis is attached to pin ST for models equipped with standard type TCB or to pin BR if bridge type TCB. Models are shipped as ordered, but because of interchangeability of chassis this should be verified.

Standard Type TCB	Although instruments equipped with standard TCB can be operated without TCB connected, its use may be desirable on some applications to guard against overheating in the event of an open thermocouple The preferred method of connecting TCB is shown in Figure 10. Use extension leadwire as required to make the connections between the instrument TC terminals and the thermocouple head. Use copper wire to connect

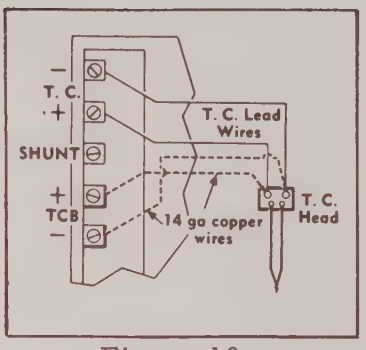


Figure 10

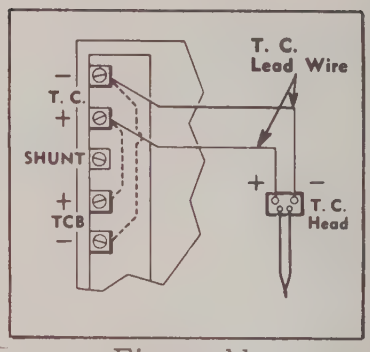


Figure 11

the TCB terminals to the thermocouple head, observing polarity. Wiring for TCB may be run in the same conduit with thermocouple leadwire. After connections are made, check for any error of indicator reading that may have resulted.

Although not recommended, an optional method of connecting TCB is to use jumpers at the instrument terminals as shown in Figure 11. As the length of leadwire used affects the amount of TCB compensation required, it is suggested that this method be used only with short leadwire lengths, 10 feet or less, and that the amount of TCB error be checked.

Standard Type TCB (continued)

To check for TCB operation, disconnect the thermocouple to simulate a broken thermocouple but leave the TCB wires connected to the leadwire. When the instrument is powered, the indicator should move upscale above the red control set pointer to a position beyond the proportional band for zero output. No power would then be applied to the load. To check for TCB error, reconnect the thermocouple, power the instrument and read the temperature with the hot junction of the thermocouple held at a steady temperature. Then disconnect the wires at the TCB terminals, and note if the indicated temperature decreases. Reconnect to see if indicated temperature increases. If a shift in reading is noticed, adjust the screw on top of the plastic cover so that the reading with TCB powered is at the same point as read with TCB disconnected. If an adjustment is made, the ambient reading will also be shifted downscale.

Note: Adjustment should be made for correct ambient temperature reading before this check is made. See section on "Cold Junction Compensation".

If the instrument is equipped with bridge type thermocouple break protection, the need for any external TCB wiring is eliminated. See Figure 12.

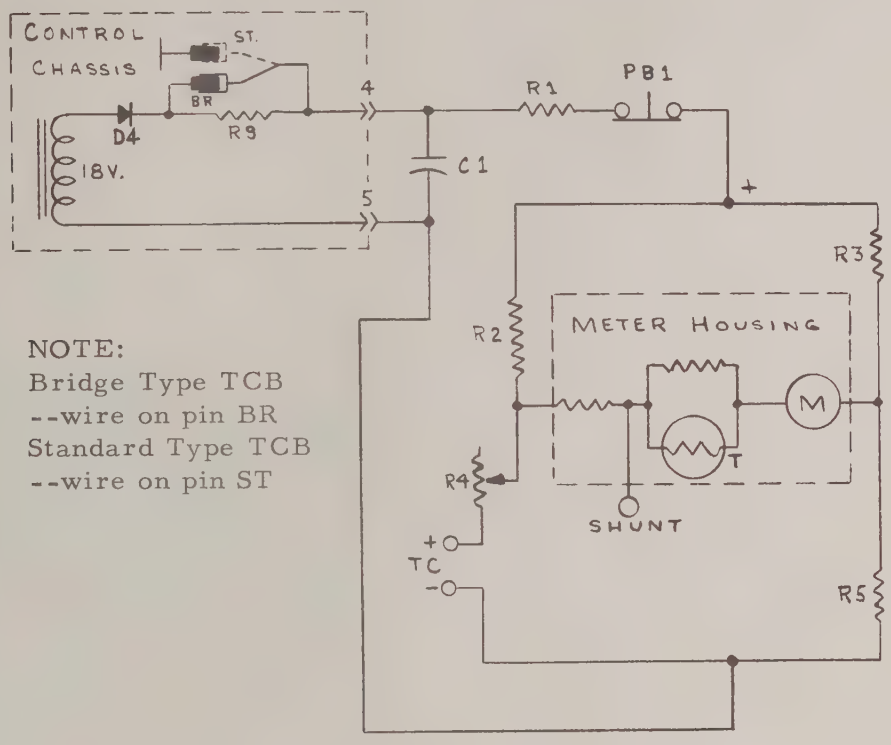


Figure 12

Bridge Type TCB

Bridge type TCB, when properly adjusted, eliminates the error that occurs with other types of TCB circuits. It also compensates for the thermocouple and leadwire resistance, as discussed in the section below. Adjustment is made in the following manner:

Remove the lower front cover, revealing the left-hand terminal strip and the push button over the words "TCB ADJ" with the adjustable potentiometer underneath. With the thermocouple connected and maintained at a steady or fixed temperature, and with the instrument powered, depress the push button and note the meter indicator reading. Then release the push button again and note the indicator reading. If there is a difference between the two readings, adjust the potentiometer with a screwdriver, with the push button released, until the meter indicator reading is the same as the initial reading when the push button was depressed. The proper adjustment is obtained when there is no discernable difference in meter readings with the push button depressed or released.

Bridge Type TCB (cont'd)	To check for TCB operation, disconnect one of the thermocouple wires to simulate a broken thermocouple. With the instrument powered, TCB is functioning properly if the meter indicator is driven upscale above the red control set pointer causing the power to the load to be turned off.

TCB, either standard or bridge type, cannot be used with ratiation detectors or the Series 350 Reference Voltage Source. An instrument with standard TCB requires only that TCB connections not be made. If instrument was purchased equipped with bridge type TCB, and it is later desired to convert for these applications, please consult your Barber-Colman field office.

Thermocouple and Leadwire Resistance Compensation

Standard Type TCB	The external resistance, for which the meter has been calibrated and as marked on the scale, is the combined resistance of the leadwire and thermocouple. Meters equipped for standard thermocouple break protection are usually calibrated for 15 ohms (Ext.Res.15 ohms) which is greater than the combined resistance of most thermocouples plus leadwire used. The balance of the resistance, 15 ohms minus the actual external resistance, is inserted on a removable resistance strip located just under the meter section. The resistance value is marked on the strip and is inserted at the time of the original order. Other values are available.
Bridge Type TCB	Instruments equipped with the bridge type TCB circuit are normally calibrated for 25 ohms which allows up to 20 ohms for the external thermocouple and leadwire resistance. An adjustable potentiometer (R4), located on the left terminal strip inside the lower compartment, is used to compensate for the difference in resistance between the allowable 20 ohms and the actual thermocouple plus leadwire resistance. The proper adjustment of this potentiometer also eliminates any TCB error. See page 15 for adjustment procedure.

Cold Junction Compensation

For measuring temperature, thermocouples are the most commonly used sensing devices. They produce a voltage when there is a temperature difference between the "hot" or measuring junction and the "cold" junction located in the meter assembly. Since the difference in temperature between the hot and cold junctions determines the amount of millivoltage produced, it is necessary to keep the cold junction temperature constant, or to compensate for any changes that occur at this point. Compensation for temperature changes at the cold junction is accomplished either

mechanically or electrically, depending on model variation. Mechanical cold junction compensation, employing a bi-metallic strip, is furnished as standard on non-suppressed range instruments unless otherwise specified. Electrical cold junction compensation is usually provided with suppressed range instruments and can be supplied with any instruments that have bridge type TCB. See Figure 13.

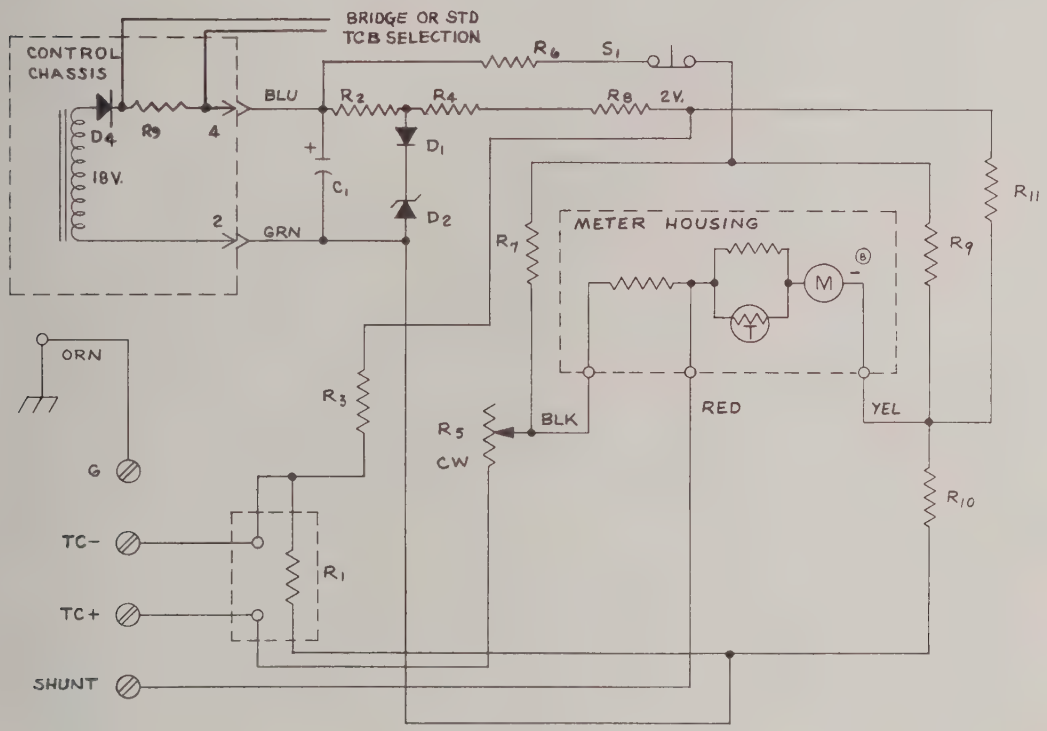


Figure 13

Notes:

1. Electrical cold junction compensation is accomplished by utilizing the resistance change, due to temperature, of resistor R1. Value depends on type of thermocouple used.

2. With electrical cold junction and suppression, value of R10 depends on the type of thermocouple and the amount of suppression desired.

Standard or Bridge TCB with Mechanical Cold Junction

After the instrument has been mounted, the cold junction reading of the meter should be checked. If the instrument is standard (i.e., with mechanical compensation), the cold junction check is made in the following manner:

Disconnect power leads and TC leadwire at the instrument. The indicator should come to rest at the ambient temperature of the meter; it is not supposed to read zero. Place a thermometer at the TC instrument terminals to read ambient temperature.

If the pointer does not indicate the ambient temperature, slowly adjust the screw located on top of the meter cover until it does. Because cold junction compensation is automatic, further corrections for changes in the ambient temperature need not be made.

Bridge TCB with Electrical Cold Junction

If the instrument has a non-suppressed range but is equipped with the electrical cold junction feature and bridge type TCB, check for proper cold junction adjustment according to the following:

The meter indicator should read zero when the instrument is unpowered. If the meter is not at zero, adjust the screw located on top of the meter cover until zero is obtained. Connect a jumper wire between TC- and TC+ and with the instrument powered, adjust the TCB potentiometer so no indicator movement occurs when the TCB push button is depressed and released. Place a thermometer at the TC instrument terminals to measure the ambient temperature reading. With the instrument still powered, the meter indicator reading should be the same as the ambient temperature reading. Further adjustments are not required because of the automatic electrical cold junction compensation.

For instruments with a suppressed range using electrical cold junction compensation:

The meter indicator should come to rest at the lowest temperature reading on the scale when the instrument is unpowered. If it does not, slowly adjust the screw located on top of the meter cover until it does. The meter is then properly adjusted and needs no further adjustment because of automatic electrical cold junction compensation.

OPERATION

Control Action

The red control set pointer is adjustable by use of the knob located just below the indicating scale. The black indicating pointer will move to indicate the temperature at the thermocouple. The Model 477P has an instantaneous response because solid state devices operate without warm-up time. When the red signal light glows, the instrument is powered and the light will remain on until the power is turned off to the instrument. If a d-c voltmeter is connected across the test jacks, assuming the output of the instrument is connected to a controller, the voltmeter output will decrease when the meter indicator approaches the control set pointer and the region where proportional control occurs.

Control Adjustments

Final control action adjustments should be made after the unit has been in operation 45 minutes and has obtained maximum stability. The controls are accessible by removing the lower front cover which is easily removed by first loosening the two screws.

Proportional Band Adjustment:

The proportional band (PB) adjustment is used to vary the proportional band from 0.5% to 5% of full scale. Turning the PB adjustment clockwise will decrease the PB, and counterclockwise will increase it. The proper PB setting is obtained in the following manner:

> With the PB adjustment fully counterclockwise (maximum PB), apply power to the controlled load. When the controlled load temperature has become thermally stable at a point near control set point, turn the PB adjustment CW slowly, decreasing the PB until the meter indicator or an external monitoring device indicates a noticeable cyclic variation. This would show on the meter as an up and downscale movement. Then turn the PB adjustment CCW in small increments, being sure to let the controlled load stabilize after each adjustment. The cyclic variations of the meter indicator and the load will decrease and the proper PB adjustment is obtained when no preceptible indicator movement occurs. With this PB setting, temperature variations of the controlled load are minimized.

Reset:

A "reset" adjustment (the slotted shaft) is located on the right front of the plug-in control chassis, accessible by removing the lower compartment cover.

Reset adjustment provides a means of aligning the meter indicator with the red control set pointer to correct for offset. If the meter indicator does not coincide with the red control set pointer after the controlled load has become thermally stable, an alignment adjustment should be made. Use a small screwdriver to reposition the reset adjustment capacitor. Turning the reset adjustment counterclockwise will shift the meter downscale so as to produce a lower temperature. Conversely, turning the reset adjustment clockwise will shift the meter indicator upscale, producing a greater temperature. The reset adjustment should be in small increments with sufficient time allowed after each adjustment to permit the controlled load to again become thermall stable. The proper reset adjustment occurs when the meter indicator coincides with the control set pointer when the load is thermally stable.

MAINTENANCE

Routine Servicing

Servicing of the instrument, in the usual sense, is not required. It is recommended, however, to make routine checks of the condition of the thermocouple, extension wire and power connections. Meter accuracy may be verified from time to time. The frequency of these checks may vary from one month to three months, depending on the extent of usage, accuracy required and the seriousness of any problems that may be created due to possible "down time".

Spare parts for emergency servicing should be kept on hand. Where a number of instruments are located together, the plug-in parts are interchangeable to allow minimum inventory.

When trouble is encountered, the serviceman should familiarize himself with the process and instrument application to determine the exact function of the instrument as applied. The instrument trouble usually can be traced to two basic problems: measurement or control.

Measurement or Control Trouble

Measurement trouble can be detected by observing the pointer position. If the measured temperature is known to be in error, check the following:

1. Open or broken thermocouple, leadwire or connector. Check visually or with a volt-ohmmeter.

2. Deteriorated thermocouple. Compare reading with a test thermocouple or check output with a Barber-Colman portable potentiometer.

3. In most applications the thermocouple is grounded through the furnace or machine to which it is attached. If this is not the case, run a wire from TC- to the ground terminal on the left-hand terminal strip and ascertain that the instrument is also grounded.

   Note: In case the thermocouple is directly in contact with a heater or similar electrical load, a 2 mfd, 200 volt capacitor should be connected between terminal TC- and ground.

4. Accidental shorts, grounds or moisture in the leadwire (especially with asbestos type insulation).

5. High resistance in leads due to loose connectors, poor splicing, dirty switch contacts, and other faulty connectors.

6. Problems caused by vibration or shock.

7. Meter accuracy. This can be checked with a Model 330P portable potentiometer.

8. Errors due to oil and grease. Do not oil or grease any part of the instrument.

9. Incorrect cold junction (ambient) setting. The correctness of this setting should be checked following any other meter servicing.

10. Incorrect TCB adjustment (see section on "Thermocouple Break Protection").

Control trouble may be detected by observing control point and indicator pointer position. If control action does not occur at control point, do the following:

1. Check electrical connectors and correctness of line voltage. Ascertain as to whether trouble is internal or external to the instrument.

2. Adjust manual reset as described on page 20.

3. If the instrument does not operate (i.e., red light does not glow), make sure the meter indicator is downscale from the control set point and turn the reset adjustment through its entire adjusting range. If the instrument then turns on, let the controlled load stabilize, after which proper reset adjustment can be made as described under "Control Adjustments". If the instrument does not turn on, further servicing or replacement of the control chassis is suggested.

Calibration Check

The instrument has been calibrated at the factory to the specified limits of accuracy. No further adjustment need be made. If, however, it is later decided to check the calibration, obtain a Barber-Colman Model 330P Portable Potentiometer, or its equivalent, and perform the following:

Standard TCB Mechanical Cold Junction	If instrument is equipped with standard TCB and mechanical cold junction compensation: Follow directions outlined in the Model 330P Instruction Manual on page 11.

Bridge TCB with Mechanical or Electrical Cold Junction

If instrument is equipped with bridge type TCB:

Remove the TC wire and short out the TC terminals by connecting a jumper wire between terminals marked TC- and TC+. Then, with the instrument powered, adjust the TCB potentiometer so no meter indicator movement occurs when the TCB push button is depressed and released. With the jumper wire then removed, and the instrument unpowered, connect a Barber-Colman 330P (or equivalent) to the thermocouple terminals and follow instructions stated below.

Bridge TCB with Mechanical Cold Junction

If instrument has mechanical cold junction compensation:

Procedure for calibrating is as outlined in the Model 330P Instruction Manual -- except that the Model 330P must be set for zero external resistance instead of the external resistance marked on the scale.

Bridge TCB with Electrical Cold Junction

If the instrument has electrical cold junction compensation and a non-suppressed range:

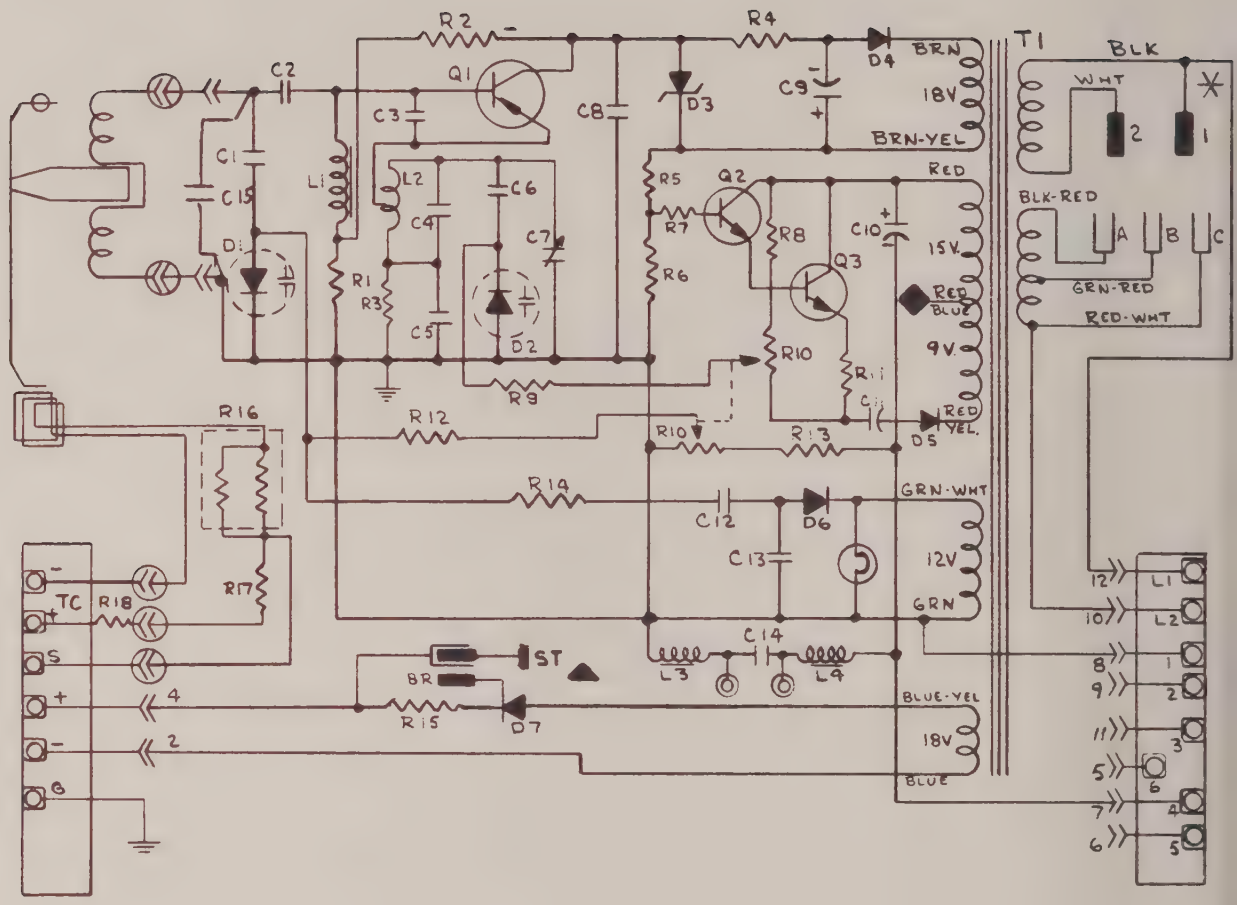
Calibrating procedure is as outlined in the Model 330P Instruction Manual except for the following: The Model 330P must be set for zero external resistance, and for a zero cold junction setting instead of ambient. Since most thermocouple tables are based on 32°F reference temperature, the 0°F millivoltage equivalent has to be added (algebrically) to the desired temperature millivoltage equivalent. For example, the proper 400°F I/C setting on the potentiometer would be:

(0°F) = -0.89 mv, and 400°F = 11.03 mv

11.03 - (-0.89) = 11.92 mv, which is the proper setting

Suppressed range instruments:

These models require a special procedure for calibrating the instrument. Contact your Barber-Colman field office if a calibration check is believed to be necessary.



✳ For 120 v connect A to 1 and C to 2.
For 208 v connect B to 2.
For 240 v connect A to 2.

◆ This connection not used on this model.

▲ Jumper in control chassis:
to pin ST for standard type TCB.
to pin BR for bridge type TCB.

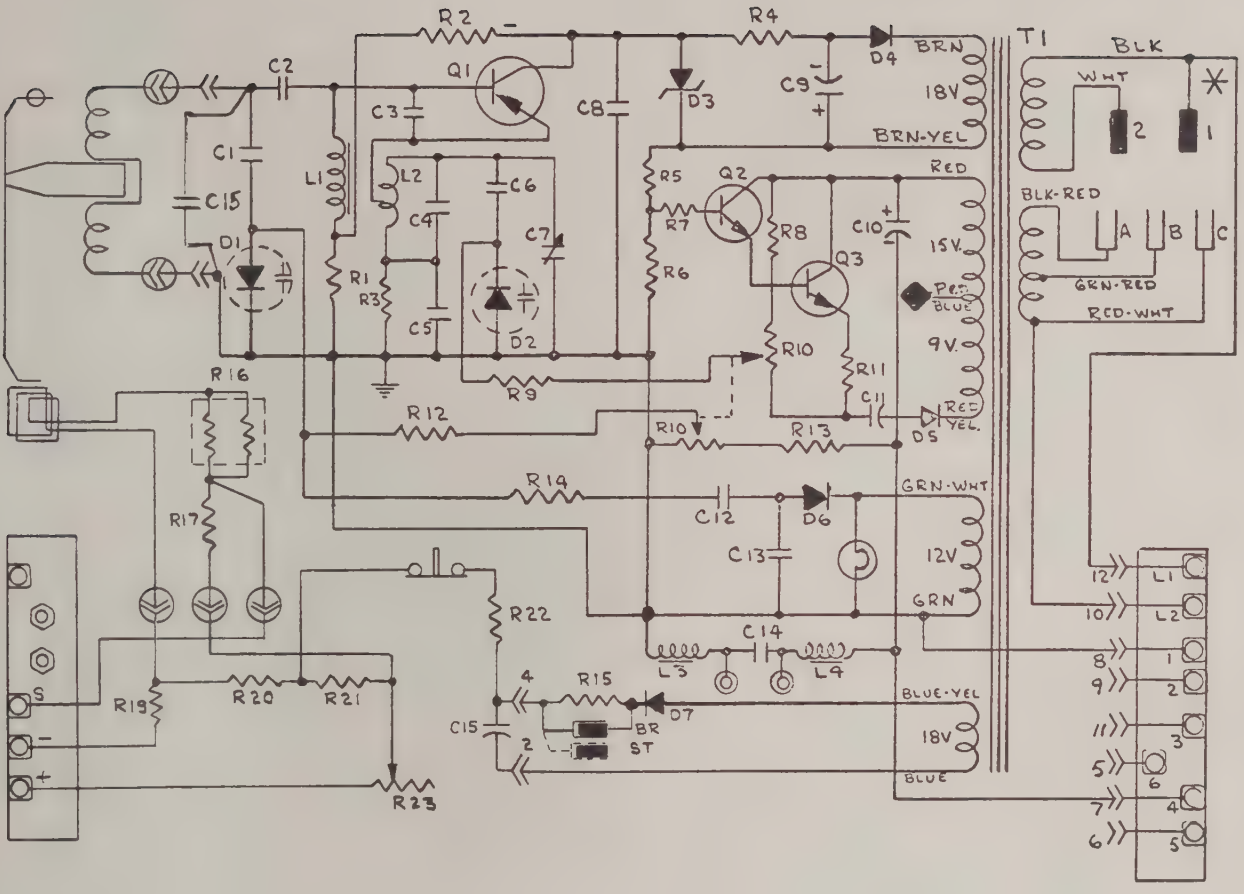
—⟨ Pins on chassis.

—⟨◉ Pins on meter.

◎ Test jack.

Figure 14

Internal Wiring Diagram
Model 477P with Standard TCB



✳ For 120 v connect A to 1 and C to 2.
For 208 v connect B to 2.
For 240 v connect A to 2.

◆ This connection not used on this model.

▲ Jumper in control chassis:
to pin ST for standard type TCB.
to pin BR for bridge type TCB.

Pins on chassis.

Pins on meter.

Test jack.

Figure 15

Internal Wiring Diagram
Model 477P with Bridge Type TCB

Replacement Parts List

Item	Part Number	Description
C1	39-080	47 mmf Capacitor
C2	39-203	270 mmf Capacitor
C3	39-212	8 mmf Capacitor
C4	39-080	47 mmf Capacitor
C5	39-203	270 mmf Capacitor
C6	39-080	47 mmf Capacitor
C7	39-160-1	2.9-35 mmf Capacitor
C8	39-103	.01 mfd Capacitor
C9	39-153	50 mfd Capacitor
C10	39-163	100 mfd Capacitor
C11	39-153	50 mfd Capacitor
C12	39-088	.0047 mfd Capacitor
C13	39-088	.0047 mfd Capacitor
C14	39-103	.01 mfd Capacitor
C15	39-227	25 mmf Capacitor
D1	37-060	Variable Voltage Capacitor Diode
D2	37-060	Variable Voltage Capacitor Diode
D3	37-098	Zener Diode
D4	EYZP-384	Diode
D5	EYZP-384	Diode
D6	37-030	Diode
D7	37-030	Diode
L1	41-133	22 mh Coil
L2	41-130	1.2 mh Coil
L3	41-124	60 mh Choke
L4	41-124	60 mh Choke
Q1	31-050	Transistor (2N2188)
Q2	31-069	Transistor (2N696)
Q3	31-069	Transistor (2N696)
R1	40-306	910 ohm Resistor
R2	40-082	33 k Resistor
R3	40-077	270 ohm Resistor
R4	CYZR-133-2	1.5 k Resistor
R5	CYZR-170-52	560 ohm Resistor
R6	CYZR-170-32	470 ohm Resistor
R7	CYZR-105	8.2 k Resistor
R8	40-070-2	47 k Resistor
R9	CYZR-170-18	4.7 megohm Resistor
R10	29-148	100 k and 100 k Dual Potentiometer
R11	40-078	15 ohm Resistor
R12	CYZR-170-18	4.7 megohm Resistor
R13	40-070-2	47 k Resistor
R14	CYZR-170-18	4.7 megohm Resistor
R15	CYZR-170-9	68 k Resistor
R16	A-3049-1	Temperature Compensator (two resistors)
R17	A-1847	Calibrating Sppol (specify range)
T1	35-142	60 cycle Transformer

MODEL 477P with STANDARD TCB ONLY

Item	Part Number	Description
R18	A-3497	External Resistance Compensator

MODEL 477P with BRIDGE TYPE TCB ONLY

R19	CYZR-326-103	5 ohm Resistor
R20	CYZR-326-54	2.5 k Resistor
R21	40-162	10 k Resistor
R22	40-070-2	47 k Resistor
R23	29-133	25 ohm Potentiometer
C15	39-068	39 mmf Capacitor

Suggested Replacement Parts to Keep on Hand

Quantity	Part Description	Part Number
2	MAZDA Pilot Lamps	36-034
1	Replacement Thermocouple	Barber-Colman can supply thermocouple assemblies, components or wire for any requirement you may have. If need be, delivery will be made in 48 hours. Contact your nearest Barber-Colman field office.
1	Indicating Meter Assembly	A-6175
1	Control Chassis	A-6003

We do not recommend electronic component replacement except by well equipped instrument repair shops.

Barber-Colman, Industrial Instruments Division, maintains service and repair facilities in many major cities in the Unites States and Canada. Consult your yellow page directory.

DEFINITION OF TERMS

CONTROL SET POINT	The position on the instrument scale to which the control point setting mechanism is set.
CONTROLLED VARIABLE	That quantity or condition which is varied by the controller so as to affect the power of the measured variable. Example: Power to an electric furnace.
CYCLING	A periodic change of the measured variable from one value to another. Oscillation and hunting are synonymous terms.
FINAL CONTROL ELEMENT	That portion of a control system which directly changes the value of the controlled variable. Example: Model 621A Power Controller.
MEASURED VARIABLE	That quantity or condition which is measured and regulated through control of the controlled variable. Example: Temperature in a furnace.
OFFSET	A sustained deviation from control point due to proportional control action. It is the difference existing at any time between control point and the actual value of the measured variable. Droop is a synonymous term.
OSCILLATION	See Cycling.
PROPORTIONAL BAND	That change in value of the measured variable that is necessary to cause full travel of the final control element. It is measured as a percent of full scale span. Throttling range is a synonymous term.
PROPORTIONAL CONTROL	Controller action in which there is a continuous linear relation between the value of the measured variable and the position of the final control element. In other words, the output of the controller is proportional to its input. Synonymous terms are throttling or modulating action.

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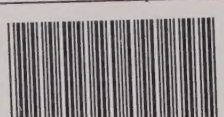

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